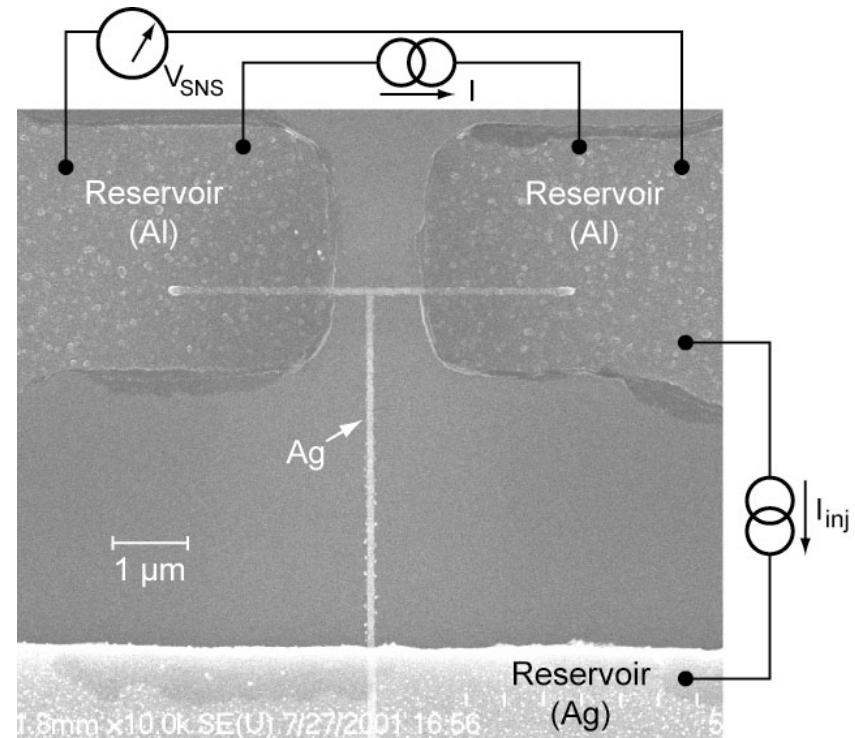


# Nonequilibrium Superconductivity-- pg. 1

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When two superconductors are separated by a sufficiently thin insulator or normal metal, a supercurrent can pass between them. This effect, named after the theorist Brian Josephson, has been studied since the early 1960's. Generally the supercurrent  $I_s$  flowing across a Josephson junction depends on the phase difference  $\phi$  between the two superconductors as  $I_s = I_c \sin(\phi)$ , where  $I_c$  is the maximum supercurrent. What a surprise, then, when the group of B.J. van Wees in Groningen discovered in 1999 that the sign of the supercurrent in a S/N/S junction can be reversed by injecting a large normal current through the interior of the junction. Under those conditions the current-phase relationship becomes  $I_s = I_c \sin(\phi + \pi)$ , hence the device is called a  $\pi$  junction.

In the van Wees experiment, the sample was cross-shaped, and the injected normal current flowed perpendicular to the direction of the supercurrent. We have observed a similar effect in the T-shaped device shown at the right, which has only three terminals rather than four. In contrast to the earlier experiment, the injected normal current in our device flows along with the supercurrent (either parallel or antiparallel) in the horizontal arms of the sample. Contrary to our intuition, the normal current and supercurrent coexist in those arms of the sample.



The T-shaped silver wire is connected to two superconducting aluminum reservoirs and one normal silver reservoir. The current-voltage characteristic of the SNS Josephson junction is measured as a function of the current injected into the junction from the normal reservoir.

# Nonequilibrium Superconductivity -- pg. 2

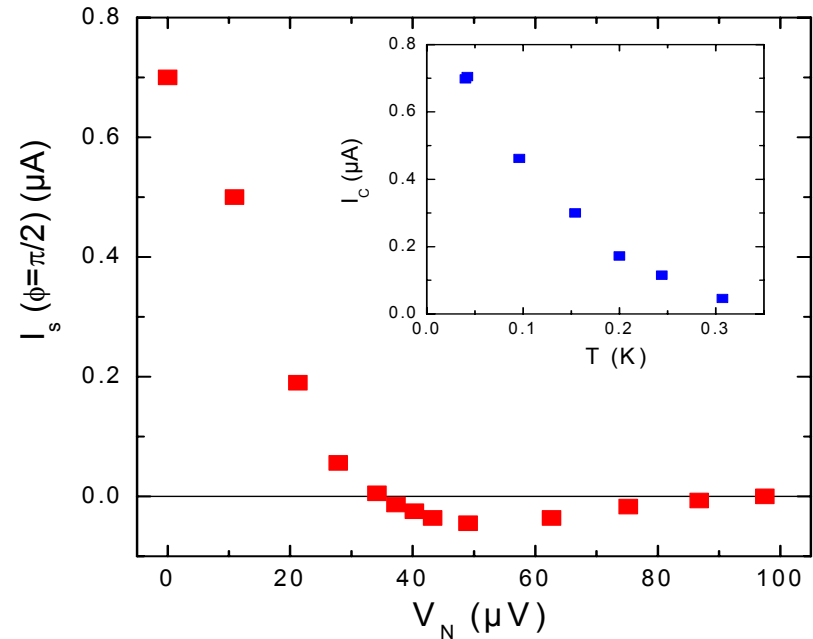
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## Educational:

Undergrads: David Bobela, Joseph Ott  
Grad students: Jian Huang, Michael Crosser,  
Ion Moraru  
Post-doc: Frederic Pierre

## Outreach Activities:

Science Day at the Mall  
Michigan Science Olympiad  
Collaborative research with Prof. Charles  
Moreau and an undergrad student Jon  
Lighthall from Albion College, MI.



The figure above shows the supercurrent  $I_s$  that flows for a fixed phase difference  $\phi=\pi/2$  between the two superconductors, as a function of the nonequilibrium driving voltage  $V_N$  applied to the normal reservoir.  $I_s$  changes sign when  $V_N$  exceeds 35  $\mu V$ , signifying the appearance of the  $\pi$  junction. The inset shows the maximum supercurrent vs. temperature under equilibrium conditions.